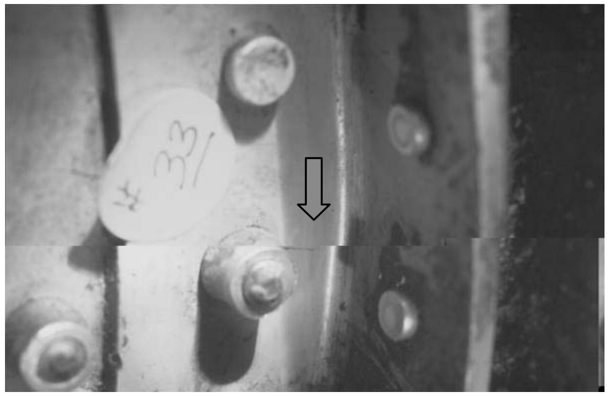
ECVP 2005

A Local Luminance Metric

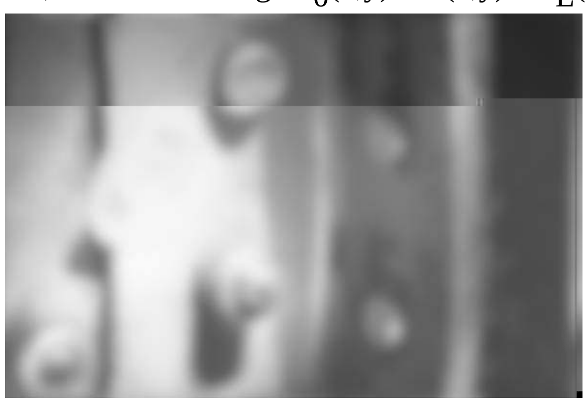
Albert J. Ahumada, NASA-Ames Research Center, *al.ahumada@nasa.gov*

Question. The contrast image $C(x,y)$ is usually computed from the luminance image $L(x,y)$ and the background luminance L_0 as $C(x,y) = (L(x,y) – L_0)/L_0$.



What should L_0 be to compute the contrast of the crack in this image?

A Simple Answer. The luminance $L_0(x,y)$ for the contrast of a point (x,y) is the average luminance near that point, the blurred image $L_0(x,y) = L(x,y) * S_L(x,y)$.



A convenient blur function is the Gaussian

$$S_L(x,y) = (1/(2\pi \sigma_L^2)) \exp(- (x^2 + y^2)/(2 \sigma_L^2)).$$

What should we use for the standard deviation σ_L?

Estimation Strategy. Find the σ_L that best predicts target detection. Ahumada and Beard (1998) used an "optical blur" low-pass filter $S_B(x,y)$ with σ_L = 1.4 arc min to get a blurred luminance image $B(x,y)$, then a "luminance-spread" low-pass filter $S_L(x,y)$ with σ_L = 0.38 deg to get a local luminance image $L_0(x,y)$. The "visible" contrast at each point was then computed as $C_V(x,y) = (B(x,y) - L_0(x,y)) / L_0(x,y)$.

Computational Simplification: For targets on a uniform background, very similar "visible" contrast values are obtained by first computing luminance contrast from the uniform background (paragraph 1) and then filtering with a contrast sensitivity function computed as the difference between the two low pass filters, CSF = $S_B(x,y)$ - $S_L(x,y)$.

Method. To estimate a local luminance spread function $S_L(x,y)$, two-component CSFs were fit to the uniform-background Modelfest detection thresholds from 16 observers. Best fitting difference-of-Gaussian CSFs were found for the 16 ModelFest observer thresholds.

Balanced Surround CSF. For the 10 constant-width, cosine-phase Gabor images, these thresholds were fit by the above equal-volume or zero-DC-response Difference-of-Gaussian CSF. Using one σ_L value for all observers gave a good fit to the thresholds (standard deviation of the errors is 3 dB). The estimated σ_L = 0.56 deg.

Unbalanced Surround CSF. When all 43 Modelfest images are included in the analysis, an unbalanced CSF of the form $S_B(x,y) – \alpha\ S_L(x,y)$ fits better, where α is about 0.8. The estimated σ_L depends somewhat on the function used to represent $S_B(x,y)$. Watson and Ahumada (2005) estimated a σ_L value of 0.42 deg for the Gaussian $S_B(x,y)$, but values ranged from 0.28 deg to 0.32 deg for the better fitting $S_B(x,y)$ functions.

Discussion. While the high frequency limb of the CSF is the result of optics and a cascade of neural factors, the low frequency limb is purely neural and can be thought of as defining local luminance. This local luminance spread can be used for predicting detection on non-uniform backgrounds. In the corresponding local luminance model, $L_0(x,y)$ is the blurred weighted average of the image and the background that preceded the image, $L_0(x,y) = (\alpha\ L(x,y) + (1- \alpha)\ L_0) * S_L\ (x,y)$.

The DC response parameter 1- α may represent the contribution of the background prior to the stimulus on a uniform background.**Acknowledgement.** Support provided by NASA Aerospace Systems.**References**

Ahumada and Beard (1998) A simple vision model for inhomogeneous image quality assessment, SID Digest 29, 641-644.

Beard, Jones, Chacon, and Ahumada (2005) Detection of blurred cracks: A step towards an empirical vision standard, Final Report for FAA Agreement DTFA-2045.

Bowen and Wilson (1994) A two-process analysis of pattern masking, Vision Research 34, 645–657.

ModelFest URL: http://vision.arc.nasa.gov/modelfest/.

Watson and Ahumada (2005) A standard model for foveal detection of spatial contrast, Journal of Vision (accepted).